DESIGN AND SIMULATION OF TRI-BAND RECTANGULAR PATCH ANTENNA USING HFSS

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Abstract:
The paper presents a compact tri band Rectangular patch antenna with microstrip feed for MIMO (Multiple Input Multiple Output) applications. The proposed antenna can resonate at 3 different frequencies of 2.3 GHz with return loss $S_{11} = -7.4448$ dB, 3.7 GHz with return loss $S_{11} = -14.1427$ dB and 4.6 GHz with return loss $S_{11} = -10.5570$ dB. Those are in C-band, 3.6-4.2 GHz allocation receive frequency for standard C-band and 4.4-4.8 GHz allocation receive frequencies for INSAT. WLAN allocation are 2.4 GHz for lower frequency and 5 GHz for high frequency. However each country has specific allocation frequency spectrum for this applications. 4.2-4.4 GHz is usually used in radio altimeters, A UWB communication system occupies the frequency range from 3.1 to 4.6 GHz. 2.4 GHz frequencies are more useful for Bluetooth, Wi-fi communications. The proposed antenna is a better choice for 4G, WLAN, Wi-MAX and Ultra Wide Band applications involving MIMO technique.

Keywords: Patch antenna, HFSS, tri-band, Impedance bandwidth, Return loss, Gain.

Introduction:
Antennas, which sends and receives the electromagnetic waves through space, plays a vital role in wireless communications. It is the basic element used to establish a wireless link between communicating devices.

The proposed Rectangular microstrip antenna with microstrip feed and its graph between return loss $S_{11}$ verses Frequency are shown in figure 1.2.

Bandwidth (sometimes just referred to as impedance bandwidth) refers to the range of frequencies a given Return Loss can be maintained. Since Return Loss is a measurement of how much power the antenna accepts from the transmission line, the impedance of the antenna must match the impedance of the transmission line for maximum power transfer. However the impedance of the antenna changes with frequency, resulting in a limited range that the antenna can be matched to the transmission line. The Bandwidth is a measure of this range.

It is typically paired with a given Return Loss or VSWR value. Radiation Efficiency is a measure of how well an antenna converts accepted power to radiated power. An efficient antenna will radiated most of the power it accepts from the transmission line. All antennas have losses associated with them, such as conductor and dielectric losses. Radiation Efficiency takes into account the loss associated in the antenna only, it should not to be confused Return Loss. The antenna accepts a certain amount of energy delivered to it by the transmission line (characterized by $S_{11}$, VSWR, or return loss), and Antenna Efficiency characterizes the amount of energy lost ‘in’ the antenna after this. It is often expressed in terms of a percentage, or in dB. For example, an efficiency of 0.8 is 80%, or -0.97 dB.

The frequency of operation of the patch antenna of Figure 1.1 is determined by the length $L$. The center frequency will be approximately given by:

$$f_c = \frac{c}{2L\sqrt{\varepsilon_r}}$$
The structure of a microstrip patch antenna is shown in Figure (1.1). Ground plane, Substrate, The patch antenna. The patch is generally made of perfect electric conducting (pec) material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate of thickness \( h \) with permittivity \( \varepsilon_r \). In this paper we use FR4Epoxy as dielectric media with relative permittivity 4.4.

**HFSS (High Frequency Structure Simulator):**

Ansoft HFSS utilizes the 3D full-wave Finite Element Method (FEM) with adaptive meshing to compute the electrical behavior of high-frequency and high-speed components. The basic mesh element is a tetrahedron. This allows solving any arbitrary 3D geometry, especially those with complex curves and shapes, in minimum time. Ansoft HFSS can be used to calculate antenna parameters such as S Parameters, radiation pattern, gain, current distributions, fields, efficiency etc. HFSS integrates simulation, modeling, visualization and automation in an user friendly environment.

With adaptive meshing and brilliant graphics, HFSS gives an unparalleled performance and complete insight to the actual radiation phenomenon in the antenna. With HFSS one can extract the parameters such as S, Y, and Z, visualize 3D electromagnetic fields (near- and far-field), and optimize design performance. An important and useful feature of this simulation engine is the availability of different kinds of port schemes. It provides lumped port, wave port, incident wave scheme etc. The accurate simulation of coplanar and microstrip lines can be done using the port schemes. The parametric set up available with HFSS is highly suitable for an antenna engineer to optimize the desired dimensions.

The first step in simulating a structure in HFSS is to define the geometry of the structure by giving the material properties and boundaries for 3D or 2D elements available in HFSS window. The next step is to draw the intended architecture using the drawing tools available in the software. The designed structure is excited using the suitable port excitation schemes. The next step is the assigning of boundary scheme. A radiation boundary filled with air is commonly used for radiating structures.

The size of air column is taken to be equal to a quarter of the free space wavelength of the lowest frequency of operation. Now, the simulation engine can be invoked by giving the proper frequency of operation and the number of frequency points. Finally the simulation results such as scattering parameters, current distributions and far field radiation pattern can be displayed. The vector as well as scalar representation of E, H and J values of the device under simulation gives a good insight into the structure under analysis.
HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a fraction of the time it would take using other techniques.

The name HFSS stands for High Frequency Structure Simulator. Ansoft pioneered the use of the Finite Element Method (FEM) for EM simulation by developing / implementing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lanczos - pade Sweep (ALPS). Today, HFSS continues to lead the industry with innovations such as Modes to Nodes and Full wave Spice.

Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for High productivity research, development, and virtual prototyping.

HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. The acronym originally stood for high frequency structural simulator. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines and packaging.

Fig 1.2: Rectangular microstrip antenna with microstrip feed and its graph between return loss $S_{11}$ versus Frequency
Fig 1.3: 3D polar plot of Gain and 3D rectangular plot of the proposed antenna

Antenna design involves, Optimised width: \( W = \frac{1}{2 f_r \sqrt{\varepsilon_0 \mu_0}} \sqrt{2/(\varepsilon_r + 1)} \)

Length:
\[ L = \frac{1}{2 f_r \sqrt{\varepsilon_{reff}} \sqrt{\varepsilon_0 \mu_0}} - 2\Delta L \]

Main properties:
Directivity:
\[ D = \begin{cases} 6.6 = 8.2 \text{ dBi}, & W \ll \lambda_0 \\ 8W/\lambda_0, & W \gg \lambda_0 \end{cases} \]

Input impedance
\[ Z_a \approx 90 \frac{\varepsilon_r^2}{\varepsilon_r - 1} \left( \frac{L}{W} \right)^2 (\Omega) \]

Bandwidth for VSWR < 2

**Conclusion:** Microstrip Patch Antennas are the only option to build the antenna with in an Integrated Circuits in case of portable devices like Bluetooth modules, wi-fi modules, Smart mobile phones and in satellite communication with its Ease of construction and integration, relatively low cost, compact low profile configuration and good flexibility. Typical applications for 1 - 20 GHz

The proposed antenna is a tri band Rectangular patch antenna with microstrip feed for MIMO (multiple input multiple output) applications. The proposed antenna can resonate at 3 different frequencies of 2.3GHz.
with return loss $S_{11} = -7.4448$ dB, 3.7 GHz with return loss $= -14.1427$ dB and 4.6GHz with return loss $S_{11} = -10.5570$ dB.

**References:**


